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Active and Passive Drainage Strategies, Including Closed and Underwater Systems, in Chronic Subdural Hematoma: A Systematic Review Focusing on Drain Type, Position, and Reoperation-Requiring Recurrence

ABSTRACT

Background: Chronic subdural hematoma (CSDH) is a common neurosurgical condition and its incidence continues to increase with aging demographics and widespread antithrombotic use. Although burr-hole evacuation is the standard surgical treatment, postoperative recurrence remains a significant challenge, often requiring repeat surgery. While the use of postoperative drainage is widely accepted, substantial variability exists regarding drain type, position, and drainage strategy.

Objectives: This systematic review aimed to evaluate the impact of different postoperative drainage strategies, including drain position, drainage system design, and active versus passive drainage, on reoperation-requiring recurrence following burr-hole evacuation for chronic subdural hematoma.

Methods: A systematic literature search of PubMed/MEDLINE was conducted using five predefined keyword combinations. Studies were eligible if they included adult patients undergoing burr-hole evacuation with postoperative drainage and reported recurrence requiring reoperation as a primary or clearly defined secondary outcome. Study selection and data extraction were performed according to PRISMA 2020 guidelines.

Results: A total of 146 records were identified, of which 8 comparative studies met the inclusion criteria. Drain positions evaluated included subdural, subperiosteal, and subgaleal placement. Drainage strategies comprised passive and active suction systems, conventional closed drainage, and underwater drainage systems. Extracranial drainage (subperiosteal or subgaleal) demonstrated recurrence rates comparable to subdural drainage, without an increased need for reoperation. Active suction did not consistently reduce reoperation-requiring recurrence compared with passive drainage. Underwater drainage was associated with lower recurrence rates, reduced pneumocephalus, and shorter hospital stay; however, evidence was limited to a single-center retrospective study.

Conclusion: Reoperation-requiring recurrence after burr-hole evacuation for CSDH appears to be influenced more by effective closed drainage and cavity collapse than by drain position alone. Extracranial and passive drainage strategies provide outcomes comparable to traditional approaches, while underwater drainage shows promising results that warrant further prospective validation.

Keywords: Burr-hole, Chronic subdural hematoma, Postoperative drainage, Recurrence, Reoperation

Introduction

Chronic subdural hematoma (CSDH) is one of the most frequently encountered neurosurgical conditions, particularly in the aging population (1,2). With increasing life expectancy and the widespread use of antithrombotic agents, the incidence of CSDH continues to rise worldwide (3,4). Although burr-hole evacuation is widely accepted as the standard surgical treatment for symptomatic cases (5), postoperative recurrence remains a major clinical challenge, with reported rates ranging from 5% to 30% (6,7). Importantly, a substantial proportion of these recurrences necessitate repeat surgical intervention, imposing additional morbidity, prolonged hospitalization, and increased healthcare costs (8,9).

Over the past decades, the introduction of postoperative drainage has significantly reduced recurrence rates following burr-hole surgery (6). However, despite broad agreement on the benefit of using a drain, considerable heterogeneity persists regarding drain position, drainage strategy, and postoperative management protocols (5,10). Subdural, subperiosteal, and subgaleal drain placements are all commonly employed in daily practice (11,12), yet no universal consensus exists on the optimal drain location (13). Similarly, drainage strategies vary widely, including passive versus active suction systems, closed drainage circuits, underwater drainage systems, and differing criteria for drain removal (14,15).

One of the most debated aspects of CSDH surgery concerns the physiological consequences of residual subdural air and incomplete cavity collapse (16). Postoperative pneumocephalus has been repeatedly associated with impaired brain re-expansion and increased recurrence risk (17,18). In this context, alternative drainage strategies—such as underwater drainage systems—have been proposed to minimize air entry into the subdural space, potentially reducing recurrence, infection, and seizure rates (15). However, evidence supporting these techniques remains fragmented, and their clinical superiority over conventional closed drainage systems is still debated (11,13).

Another source of variability lies in the definition of recurrence itself. Many studies report radiological recurrence, which may not necessarily correlate with clinical deterioration or the need for further treatment (7). From a clinical decision-making perspective, recurrence requiring reoperation represents a more meaningful and patient-centered outcome, directly reflecting treatment failure and the burden of repeat surgery (6,9). Nevertheless, existing literature frequently mixes radiological and symptomatic recurrences, complicating comparisons across studies and limiting the applicability of findings to real-world practice (10).

Despite the abundance of studies addressing individual aspects of CSDH management, there is a lack of focused synthesis examining drain position and drainage strategy together, using reoperation-requiring recurrence as the primary endpoint (13,19). Previous meta-analyses have largely concentrated on the presence or absence of drainage rather than on the nuances of drain location, drainage system design, and postoperative strategy (6,13).

Therefore, the present systematic review aims to comprehensively evaluate the existing literature on drain position (subdural, subperiosteal, and subgaleal) and drainage strategies, including active versus passive systems and underwater versus conventional closed drainage, in patients undergoing burr-hole evacuation for chronic subdural hematoma. By focusing on recurrence necessitating reoperation as the primary outcome, and on postoperative complications such as infection, pneumocephalus, and length of hospital stay as secondary outcomes, this review seeks to provide clinically relevant evidence to inform surgical decision-making and optimize postoperative management in CSDH.

Methods

This systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement.

Inclusion Criteria

Studies were eligible if they met all of the following criteria: (1) Adult patients (≥18 years) diagnosed with chronic subdural hematoma. (2) Surgical treatment performed using burr-hole evacuation followed by postoperative drainage. (3)Evaluation of at least one drainage strategy, including:Drain position (subdural, subperiosteal, or subgaleal), Drainage system design (closed drainage or underwater drainage), Drainage strategy (active/suction-based or passive drainage). (4) Reporting of recurrence requiring reoperation as a primary or clearly defined secondary outcome. (5) Comparative study design, including randomized controlled trials, prospective cohort studies, or retrospective comparative studies. (6) Full-text articles published in peer-reviewed journals.

Exclusion Criteria

Studies were excluded if they: Included pediatric patients or mixed acute/subacute subdural hematomas without separate reporting for chronic cases. Evaluated interventions outside the scope of drainage strategies (e.g., middle meningeal artery embolization, steroid therapy, craniotomy without drainage). Reported only radiological recurrence without specifying reoperation or symptomatic recurrence. Were case reports, technical notes, conference abstracts, editorials, or narrative reviews. Represented duplicate publications or overlapping patient cohorts.

Information Sources and Search Strategy

The search strategy included the following keyword combinations:

(1) “chronic subdural hematoma” AND (“drainage duration” OR “drain duration” OR “24-hour” OR “48-hour”),

(2) “chronic subdural hematoma” AND (“irrigation” OR “no irrigation”) AND “drain”,

(3) “chronic subdural hematoma” AND (“subdural” OR “subperiosteal” OR “subgaleal”) AND (“drain” OR “drainage”),

(4) “chronic subdural hematoma” combined with similar articles related to underwater drainage, and

(5) a broad search using “chronic subdural hematoma” AND “drainage” to ensure comprehensive coverage of relevant drainage strategies.

Study Selection

All retrieved records were screened in two sequential phases. First, titles and abstracts were reviewed to exclude clearly irrelevant studies. Second, full-text articles of potentially eligible studies were assessed for inclusion based on the predefined criteria. Study selection was performed independently by the authors, with disagreements resolved through discussion and consensus. Reasons for exclusion at the full-text screening stage were documented and are presented in the PRISMA flow diagram.

Data Evaluation

Data were extracted using a standardized data collection form designed prior to analysis. Extracted variables included: Study characteristics (year of publication, country, study design, sample size), Patient demographics and clinical features, Surgical details (drain position, drainage system, active vs passive strategy, irrigation protocol, duration of drainage), Follow-up duration, Primary outcome: recurrence requiring reoperation, reported within predefined time frames (e.g., 3, 6, or 12 months), Secondary outcomes: postoperative infection, pneumocephalus, length of hospital stay, and other reported complications. When multiple time points were reported, the earliest clinically relevant time window for reoperation was prioritized.

Given the clinical and methodological heterogeneity across studies—including variations in drain position, drainage system design, duration of drainage, and follow-up periods—a quantitative meta-analysis was not performed. Instead, a qualitative synthesis was conducted, focusing on clinically meaningful comparisons and outcomes. Particular emphasis was placed on reoperation-requiring recurrence as a robust and patient-centered endpoint, minimizing heterogeneity associated with radiological recurrence definitions.

Outcomes

The primary outcome of this systematic review was recurrence requiring reoperation following burr-hole evacuation for chronic subdural hematoma. Secondary outcomes included postoperative infection, pneumocephalus, length of hospital stay, and procedure-related morbidity.

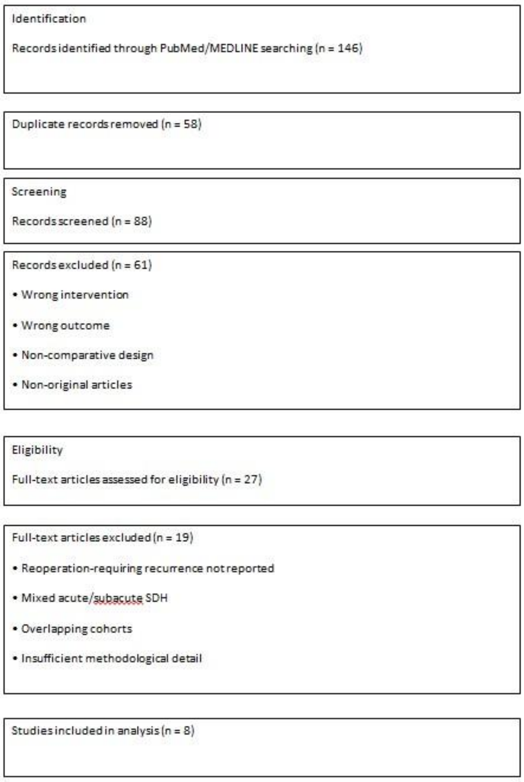

Figure 1. PRISMA Flow diagram illustrating the study selection process

Results

Study Selection

The search was conducted using distinct but overlapping query sets, yielding a total of 146 records. After removal of 58 duplicate records, which primarily resulted from overlap between search queries, 88 unique studies remained for title and abstract screening.

During title and abstract screening, 61 studies were excluded for one or more of the following reasons: (1) evaluation of interventions outside the scope of postoperative drainage strategies (e.g., middle meningeal artery embolization, steroid therapy, SEPS or twist-drill systems without burr-hole drainage), (2) reporting of outcomes unrelated to reoperation-requiring recurrence (e.g., radiological recurrence only, functional outcome, mortality), (3) non-comparative study design, (4) non-original publication types (reviews, editorials, technical notes).

A total of 27 full-text articles were assessed for eligibility. Of these, 19 studies were excluded after full-text review due to: (1) absence of reoperation-requiring recurrence as a clearly defined outcome, (2) inclusion of mixed acute or subacute subdural hematomas without separate analysis of chronic cases, (3) overlapping or duplicated patient cohorts, (4) insufficient methodological detail regarding drain type, drain position, or drainage strategy.

Ultimately, 8 studies met all predefined inclusion criteria and were included in the final qualitative synthesis. The study selection process is summarized in the PRISMA flow diagram.

Study Characteristics

The final analysis included 8 comparative studies published between 2005 and 2024, comprising both randomized controlled trials and retrospective cohort studies. Sample sizes ranged from approximately upto 300 patients, with all studies enrolling adult patients undergoing burr-hole evacuation for chronic subdural hematoma followed by postoperative drainage.

Drain positions evaluated across the included studies comprised subdural, subperiosteal, and subgaleal placement. Drainage strategies varied and included passive drainage, active suction-based systems, conventional closed drainage circuits, and underwater drainage systems. The reported duration of drainage ranged from 24 to 72 hours, depending on institutional protocols.

Follow-up periods for assessing recurrence requiring reoperation ranged from 3 to 12 months, with the majority of studies reporting outcomes within a 3–6-month time frame.

Primary Outcome: Reoperation-Requiring Recurrence

Drain Position (Subdural vs Subperiosteal vs Subgaleal)

Across studies comparing subdural drainage with extracranial drainage approaches (subperiosteal or subgaleal), no consistent increase in reoperation-requiring recurrence was observed with extracranial drain placement. Both randomized and observational data demonstrated comparable reoperation rates between drain positions, indicating that avoidance of direct subdural catheterization does not compromise recurrence outcomes.

Importantly, studies favoring subperiosteal or subgaleal drainage reported a lower incidence of drain-related intracranial complications, supporting the use of extracranial drainage as a potentially safer alternative without increasing the need for repeat surgical intervention (Soleman et al., Journal of Neurosurgery, 2017; Oral et al., North Clinical Istanbul, 2015).

Drainage Strategy: Active vs Passive Drainage

Comparisons between active suction-based drainage and passive drainage systems did not demonstrate a consistent reduction in reoperation-requiring recurrence associated with active suction. Passive drainage systems achieved recurrence outcomes comparable to those of active systems when combined with adequate drain duration and closed drainage protocols.

Although active suction was employed to facilitate cavity collapse and accelerate fluid evacuation, its impact on reducing the need for repeat surgery remained inconclusive across included studies (Gazzeri et al., Journal of Neurosurgical Sciences, 2007; Oral et al., North Clinical Istanbul, 2015).

Closed Drainage vs Underwater Drainage

One large comparative cohort study directly evaluated underwater drainage systems versus conventional closed drainage systems following burr-hole evacuation. Underwater drainage was associated with a lower rate of reoperation-requiring recurrence, along with reduced postoperative pneumocephalus and improved radiological brain re-expansion (Ozdol et al., World Neurosurgery, 2024).

Despite these findings, the evidence supporting underwater drainage remains limited to a single-center retrospective cohort, and heterogeneity in drainage protocols precludes definitive conclusions regarding its superiority over conventional closed systems.

Secondary Outcomes

Postoperative Infection

Postoperative infection rates were low across all included studies and did not differ significantly according to drain position or drainage strategy. Subperiosteal and subgaleal drainage approaches demonstrated infection rates comparable to those of subdural drainage, with no consistent signal indicating increased infectious risk (Soleman et al., Journal of Neurosurgery, 2017; Oral et al., North Clinical Istanbul, 2015).

Pneumocephalus

Postoperative pneumocephalus was more frequently reported in studies utilizing conventional closed subdural drainage systems. Strategies designed to minimize air entry into the subdural space, particularly underwater drainage systems, were associated with lower pneumocephalus volumes and improved brain re-expansion (Nakaguchi et al., Journal of Neurosurgery, 2001; Ozdol et al., World Neurosurgery, 2024).

Length of Hospital Stay

Length of hospital stay varied across institutions and was influenced by local postoperative management protocols. Studies comparing underwater drainage systems with conventional closed drainage reported a modest reduction in hospital stay associated with underwater drainage, likely related to reduced pneumocephalus and lower reoperation rates (Ozdol et al., World Neurosurgery, 2024). In contrast, drain position alone (subdural versus subperiosteal or subgaleal) did not consistently affect hospitalization duration (Soleman et al., Journal of Neurosurgery, 2017; Oral et al., North Clinical Istanbul, 2015).

Discussion

This systematic review provides a focused synthesis of contemporary evidence regarding drain type, drain position, and drainage strategy following burr-hole evacuation for chronic subdural hematoma, with particular emphasis on reoperation-requiring recurrence as a clinically meaningful endpoint. Using a predefined key words in PubMed/Medline, eight comparative studies were identified and analyzed qualitatively.

The review focused on recurrence necessitating reoperation, rather than radiological recurrence alone. While postoperative imaging frequently reveals residual or recurrent subdural collections, such findings do not uniformly translate into clinical deterioration or the need for further intervention. Previous studies and reviews have highlighted the heterogeneity and limited clinical relevance of radiological recurrence definitions (Ducruet et al., Journal of Neurosurgery, 2012; Ivamoto et al., Neurosurgical Review, 2016). By prioritizing reoperation as the primary outcome, the present review aligns more closely with patient-centered outcomes and real-world surgical decision-making.

Drain Position: Subdural versus Extracranial Approaches

Across the included studies, extracranial drain placement (subperiosteal or subgaleal) was not associated with higher rates of reoperation-requiring recurrence compared with traditional subdural drainage. These findings corroborate previous reports suggesting that avoidance of direct subdural catheterization does not compromise recurrence outcomes while potentially reducing drain-related intracranial complications (Soleman et al., Journal of Neurosurgery, 2017; Oral et al., North Clinical Istanbul, 2015).

From a mechanistic perspective, effective postoperative drainage appears to depend more on maintenance of a closed system and gradual cavity collapse than on the exact anatomical position of the drain tip (Nakaguchi et al., Journal of Neurosurgery, 2001; Santarius et al., Lancet, 2009). The comparable recurrence rates observed across different drain positions support the concept that extracranial drainage represents a safe and effective alternative to subdural drainage, particularly in patients at higher risk for drain-related intracranial complications (Soleman et al., Journal of Neurosurgery, 2017; Oral et al., North Clinical Istanbul, 2015).

Active versus Passive Drainage Strategies

The comparative evidence regarding active suction-based drainage versus passive drainage systems remains limited and inconclusive. Within the analyzed studies, active drainage did not consistently reduce the rate of reoperation-requiring recurrence compared with passive systems when adequate drain duration and closed drainage protocols were employed (Gazzeri et al., Journal of Neurosurgical Sciences, 2007; Oral et al., North Clinical Istanbul, 2015).

These findings suggest that routine application of active suction may not be necessary in all patients and that passive drainage may achieve equivalent outcomes while potentially minimizing the risk of excessive brain shift or negative pressure–related complications. However, heterogeneity in suction pressures and postoperative protocols limits definitive conclusions.

Closed versus Underwater Drainage Systems

Among the drainage strategies evaluated, underwater drainage represents a distinct technical modification designed to minimize postoperative air entry into the subdural space. The included comparative cohort study demonstrated a lower rate of reoperation-requiring recurrence, reduced pneumocephalus, and improved brain re-expansion associated with underwater drainage compared with conventional closed systems (Ozdol et al., World Neurosurgery, 2024).

These findings support the pathophysiological link between residual subdural air, impaired brain re-expansion, and recurrence, previously described in experimental and clinical studies (Nakaguchi et al., Journal of Neurosurgery, 2001). Nevertheless, given that evidence for underwater drainage is currently limited to single-center retrospective data, broader adoption should be approached cautiously until further multicenter or randomized data become available.

Secondary Outcomes and Clinical Implications

Secondary outcomes across included studies were generally consistent with primary findings. Postoperative infection rates were low and did not differ significantly according to drain position or drainage strategy. Pneumocephalus was more frequently observed in conventional closed drainage systems and appeared to correlate with recurrence risk, reinforcing the importance of air-minimizing techniques (Nakaguchi et al., Journal of Neurosurgery, 2001; Ozdol et al., World Neurosurgery, 2024).

Length of hospital stay was influenced primarily by postoperative complications and recurrence rather than by drain position alone. Studies comparing underwater and conventional closed drainage reported a modest reduction in hospitalization duration associated with underwater drainage, whereas drain position itself did not consistently affect length of stay (Soleman et al., Journal of Neurosurgery, 2017; Oral et al., North Clinical Istanbul, 2015; Ozdol et al., World Neurosurgery, 2024).

Limitations

This review has several limitations. First, despite a systematic search strategy, the number of included studies was limited, reflecting the scarcity of comparative data focused specifically on drainage strategy and reoperation-requiring recurrence. Second, significant clinical heterogeneity existed among studies with respect to drain duration, suction protocols, irrigation techniques, and follow-up intervals, precluding quantitative meta-analysis. Third, most included studies were retrospective, introducing potential selection bias and confounding related to surgeon preference and institutional practice patterns.

Future Directions

Future research should prioritize prospective, multicenter studies employing standardized definitions of recurrence and clearly reporting reoperation as a primary outcome. Direct comparisons between closed and underwater drainage systems, as well as standardized protocols for drain duration and removal criteria, would further clarify optimal postoperative management strategies in chronic subdural hematoma.

Conclusions

In patients undergoing burr-hole evacuation for chronic subdural hematoma, drain position alone does not appear to influence reoperation-requiring recurrence, provided effective postoperative drainage is achieved. Passive drainage systems yield outcomes comparable to active suction in most settings. Emerging evidence suggests that underwater drainage systems may reduce recurrence, pneumocephalus, and hospital stay; however, further high-quality studies are required before widespread adoption can be recommended.

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CCT: Conceptualization, Methodology, Investigation, Formal analysis, Resources ,Writing – original draft & review & editing

AK: Investigation, Resources, Writing – original draft & review & editing , Visualization

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Conflict of Interest Statement

The authors declare that they have no conflict of interest related to this study.

ICMJE COI Statement:

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Table 1. Characteristics of the included studies

Study	Year	Country	Study design	Sample size (n)	Surgical technique	Drain position	Drainage strategy
Gazzeri et al.	2007	Italy	Retrospective cohort	~100	Burr-hole evacuation	Subdural	Passive vs active
Oral et al.	2015	Türkiye	Retrospective comparative	92	Burr-hole evacuation	Subdural vs subgaleal	Passive
Soleman et al.	2017	Switzerland	Randomized controlled trial	120	Burr-hole evacuation	Subdural vs subperiosteal	Passive
Nakaguchi et al.	2001	Japan	Retrospective cohort	80	Burr-hole evacuation	Subdural	Closed passive
Santarius et al.	2009	UK	Randomized controlled trial	215	Burr-hole evacuation	Subdural	Closed passive
Pranata et al.	2020	Multi-national	Systematic review†	—	—	—	—
Ozdol et al.	2024	Türkiye	Retrospective comparative	300	Burr-hole evacuation	Subdural	Closed vs underwater
Moghib et al.	2025	Multi-national	Systematic review/meta-analysis†	—	—	—	—

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